Near Earth Networks Conference

June 24, 2004

SPACE COMMUNICATIONS PROGRAM

(Formerly Mission Services Program)

Code 450

June 24, 2004

Goddard Space Flight Center

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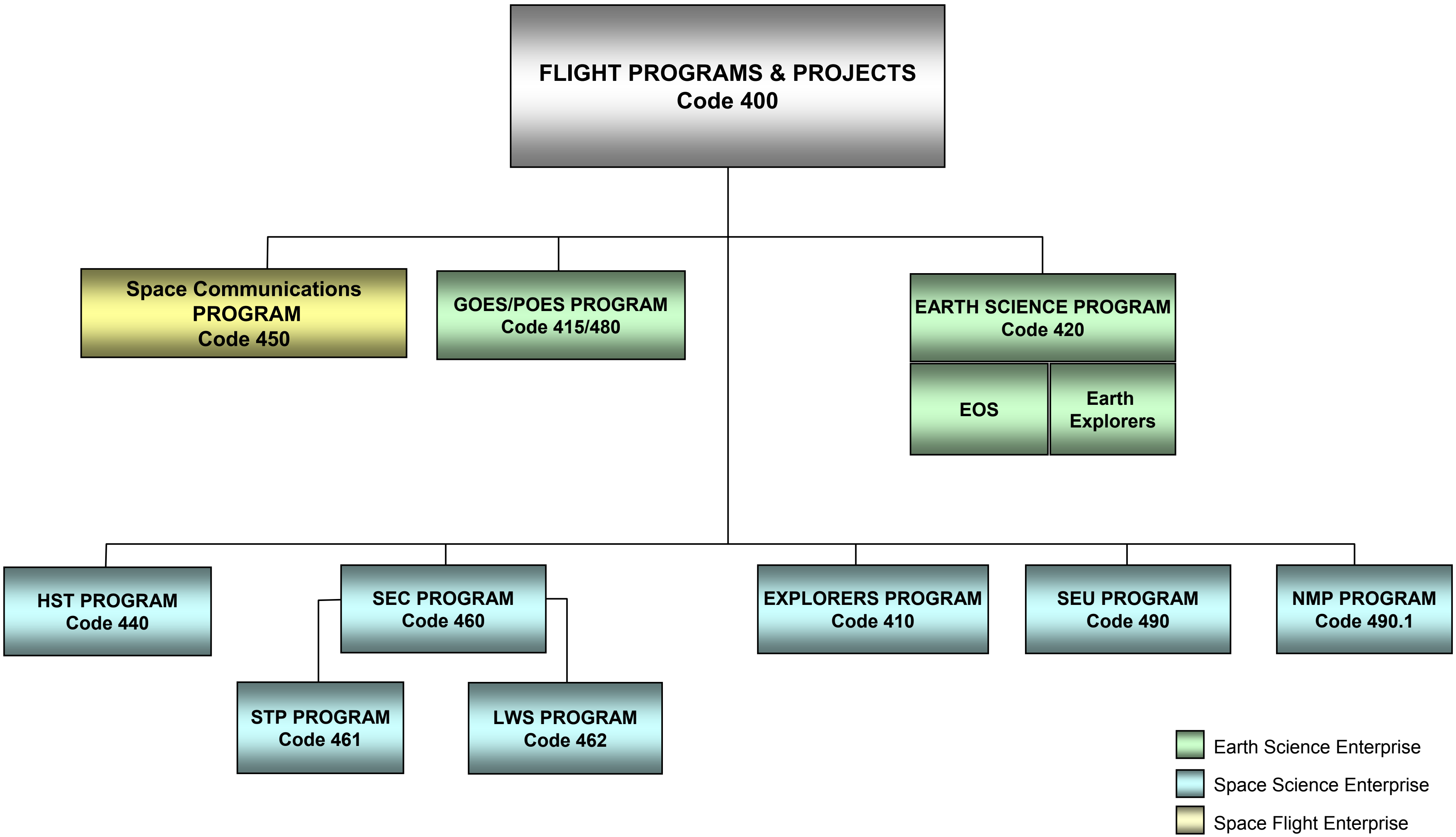
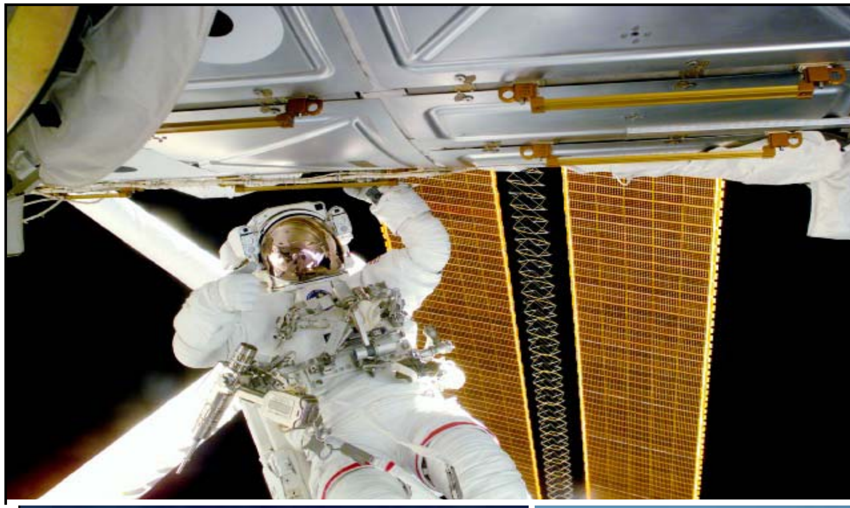
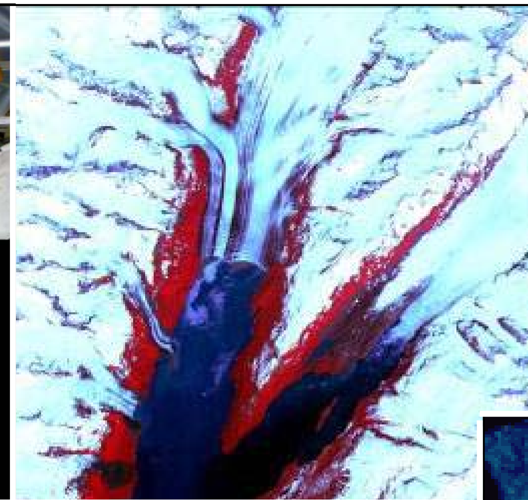
Flight Programs & Projects

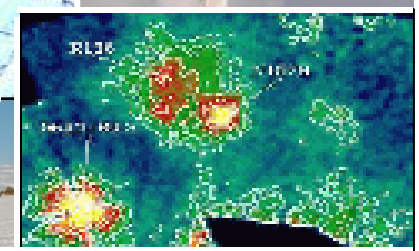


Space Communications Program Code 450

- Transformational Communications Architecture
- Customer Commitment Office
- Program Integration
- Space Network Project
- Ground Network Project
- Tracking & Data Relay Satellite Continuation Project
- Mars Laser Communication Demonstration

SCP Customer Support





Major Program Changes

- Pre-Formulation studies for TDRS Continuation
  - Current analysis indicates need to replenish by 2012/13
  - Evolutionary changes under study
- MARS Laser Communications Demonstration
  - Project team formed with JPL and MIT Lincoln Labs
  - Scheduled for 2009 launch
- Satellite Laser Ranging systems added to the GN project
- Support to Space Communications Architecture studies
  - NASA Space Architect / Code M 3
  - Transformational Communications Architecture

Future Mission Space Communications Needs

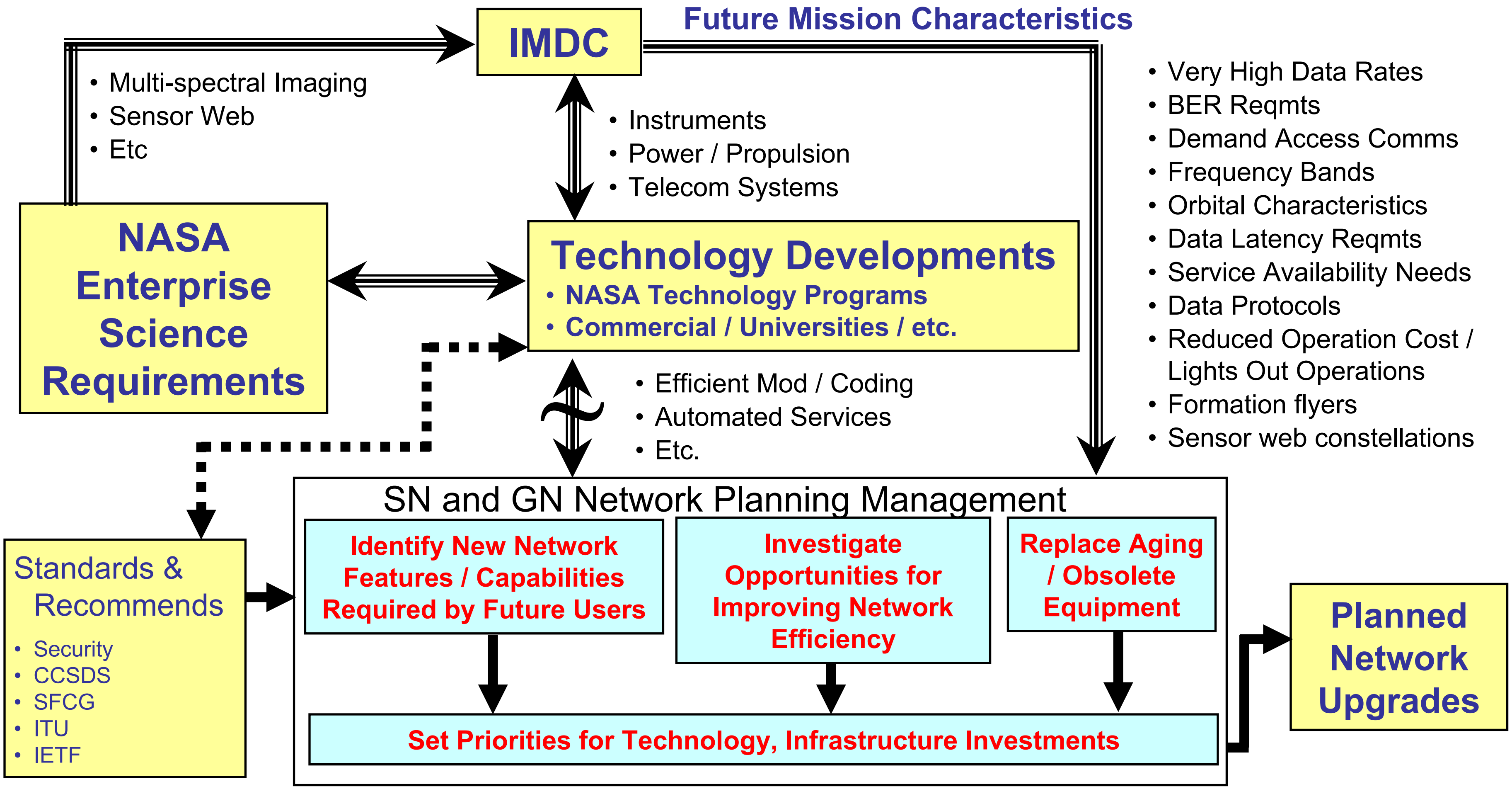
- **Presidents Space Exploration Initiative**
  - **Launch, Early Orbit, injection and reentry coverage**
    - SN and GN similar to today
  - **Must adapt to potential for Early phase out of some legacy missions**
    - Shuttle and HST (possibly ISS in 2017)
  - **High bandwidth lunar and Deep Space Comm**
    - Ka-Band and /or Optical
    - Enable Earth Science Instruments around other planets
    - Lunar robotic reconn missions as early as 2008
    - Likely GN or DSN use first 10's to 100's of Mbps from the Moon
    - Transition to optical would increase capacity X 10 or more
      - Space based optical preferable - Higher availability
  - **Precision navigation**
    - S-Band Range and Range Rate
    - Beacons and Optical also under consideration

Future Mission Space Communications Needs (Continued)

- **Space and Earth science missions**
  - **Continued desire for larger bandwidth**
    - Near earth and Deep Space
      - Ka-Band and or Optical under consideration
      - GN approach likely for missions W/O latency need
      - SN preferable for Highest bandwidth / low latency
  - **Transparency “Like a node on the Internet”**
    - On Demand communications
    - Sensor WEBS / Science alerts / 911
    - Many formations and constellations under study
  - **Continued desire for S-Band tracking & Health & Safety links**
    - LEO and contingency
    - Navigation Beacon under study for ESE and others

Approach

- The approach used in identifying desired new SN / GN capabilities for the Code 450 roadmap is outlined below:

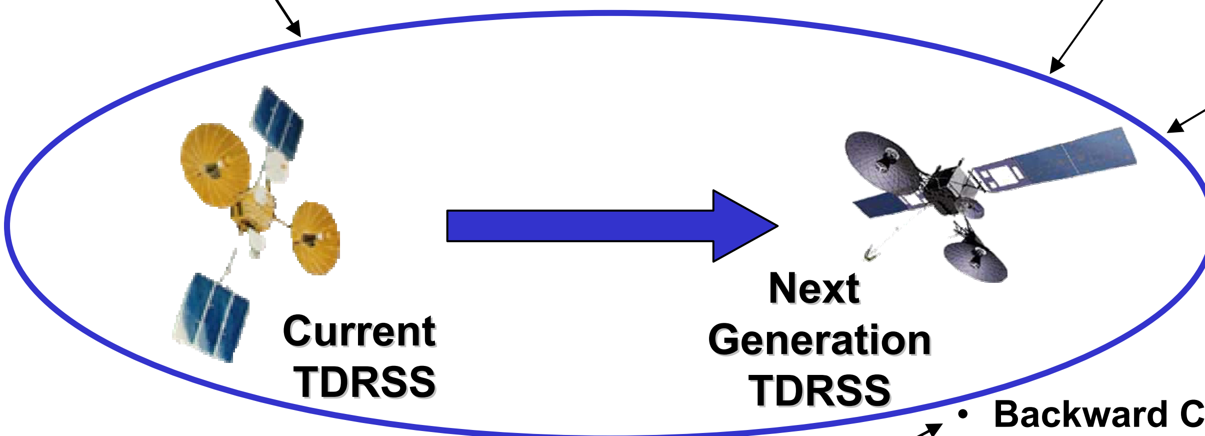


SN Evolution

Sensor Web Capability

Software Radios

Formation Flyers

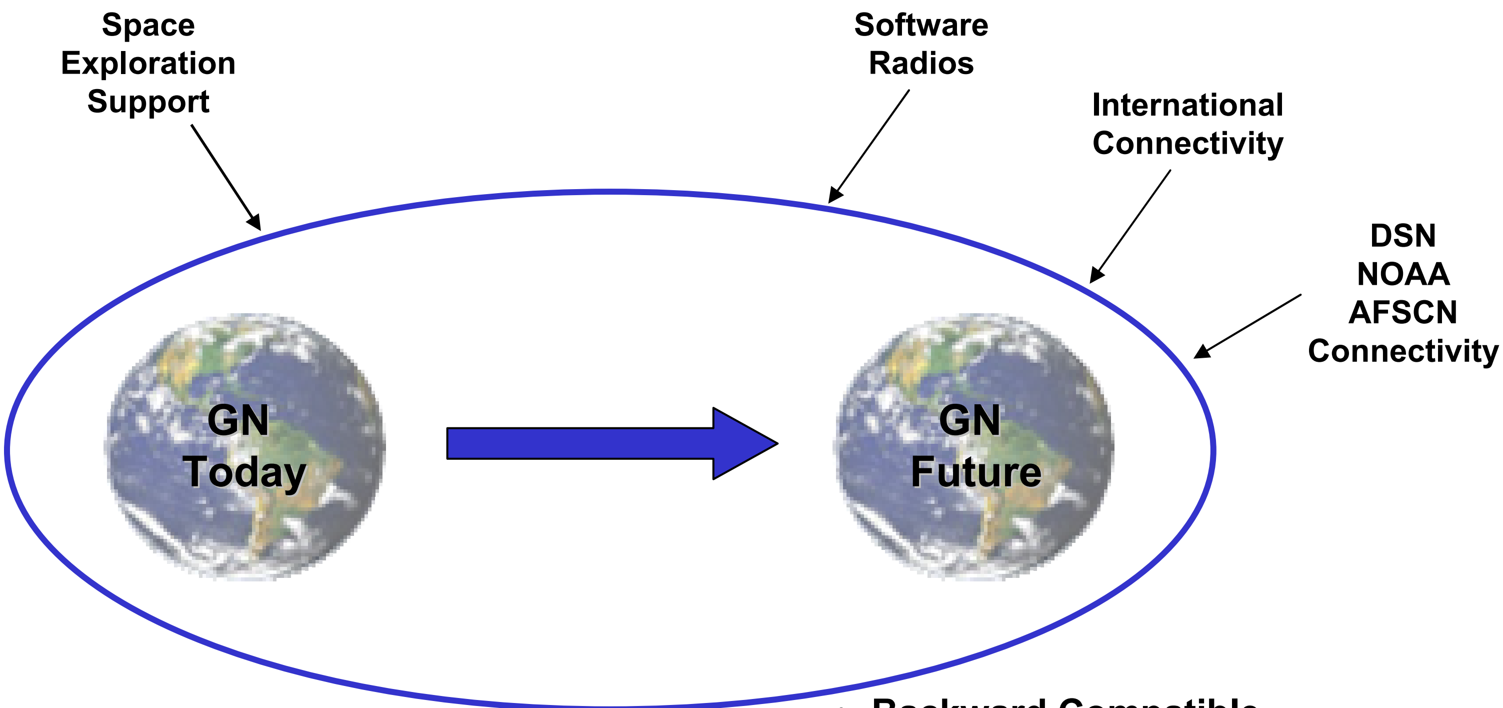


Schedule Free Service

- Ku-Band (300 Mbps)
- Ka-Band (550 Mbps)
- SSA (6 Mbps)
- MA (300 Kbps)
- DAS
- Fast Forward
- IP/SLE/CCSDS
- Beacon (TASS)
- SWSI (SNAS)

- Backward Compatible
- Full 2-way Demand Access
- Ka-Band (1.2 to 1.5 Gbps)
- MA Enhancements
  - FOV and G/T
  - Beacon
  - Freq & Polarization Flexibility
- Optical
  - LEO Including Opt MA
  - L1/L2
  - Deep Space
- Government Partnerships

GN Evolution

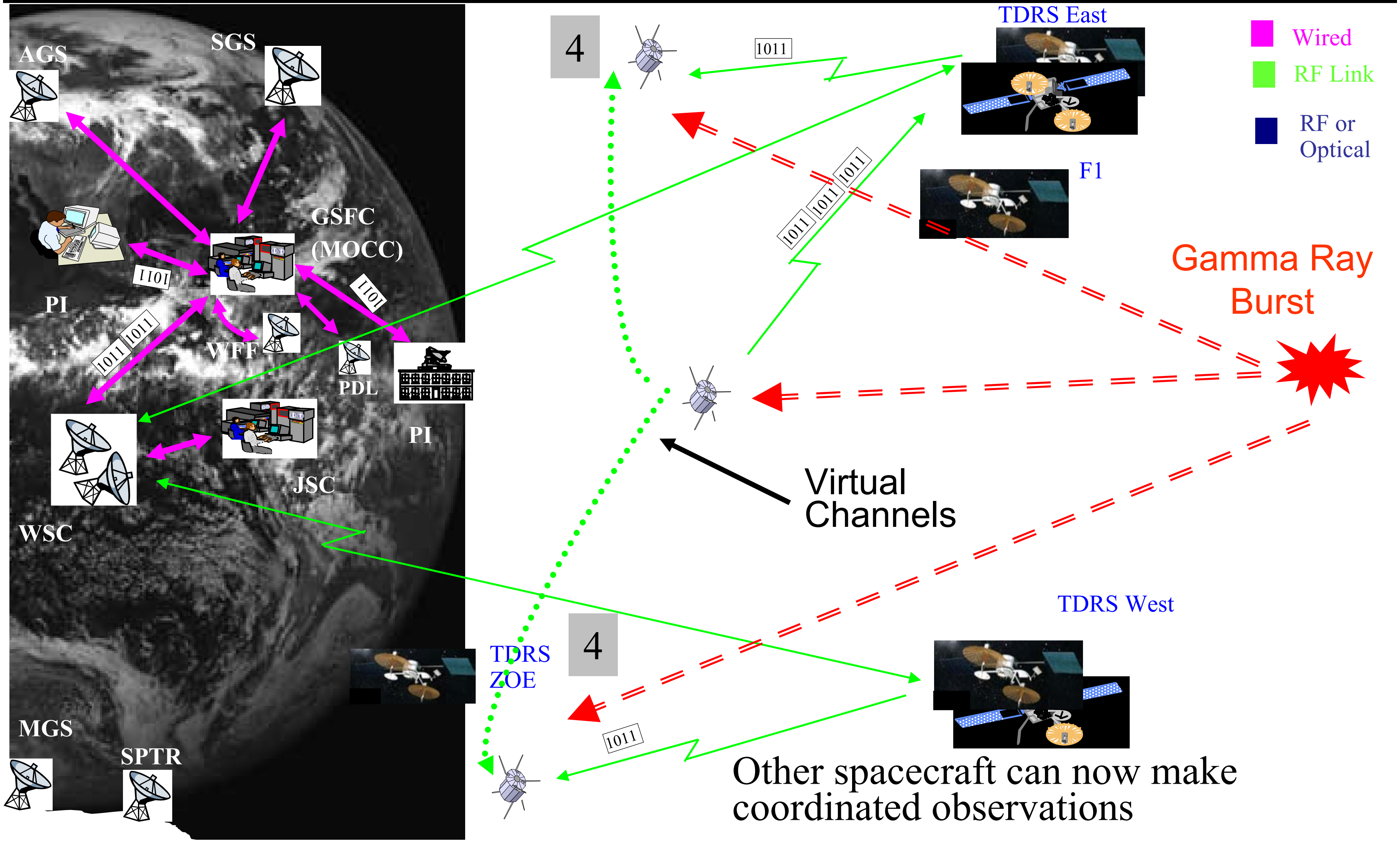


- S-Band (5 Mbps)
- X-Band (150 Mbps)
- Commercial & Government Partnerships

- Backward Compatible
- Ka (1 Gbps)
- Bandwidth Efficient Modulation & Coding
- IP/SLE/CCSDS
- Space Based Range Services
- Smart Antennas (phased arrays)
- Autonomous and Eye Safe SLR
- Additional Partnerships

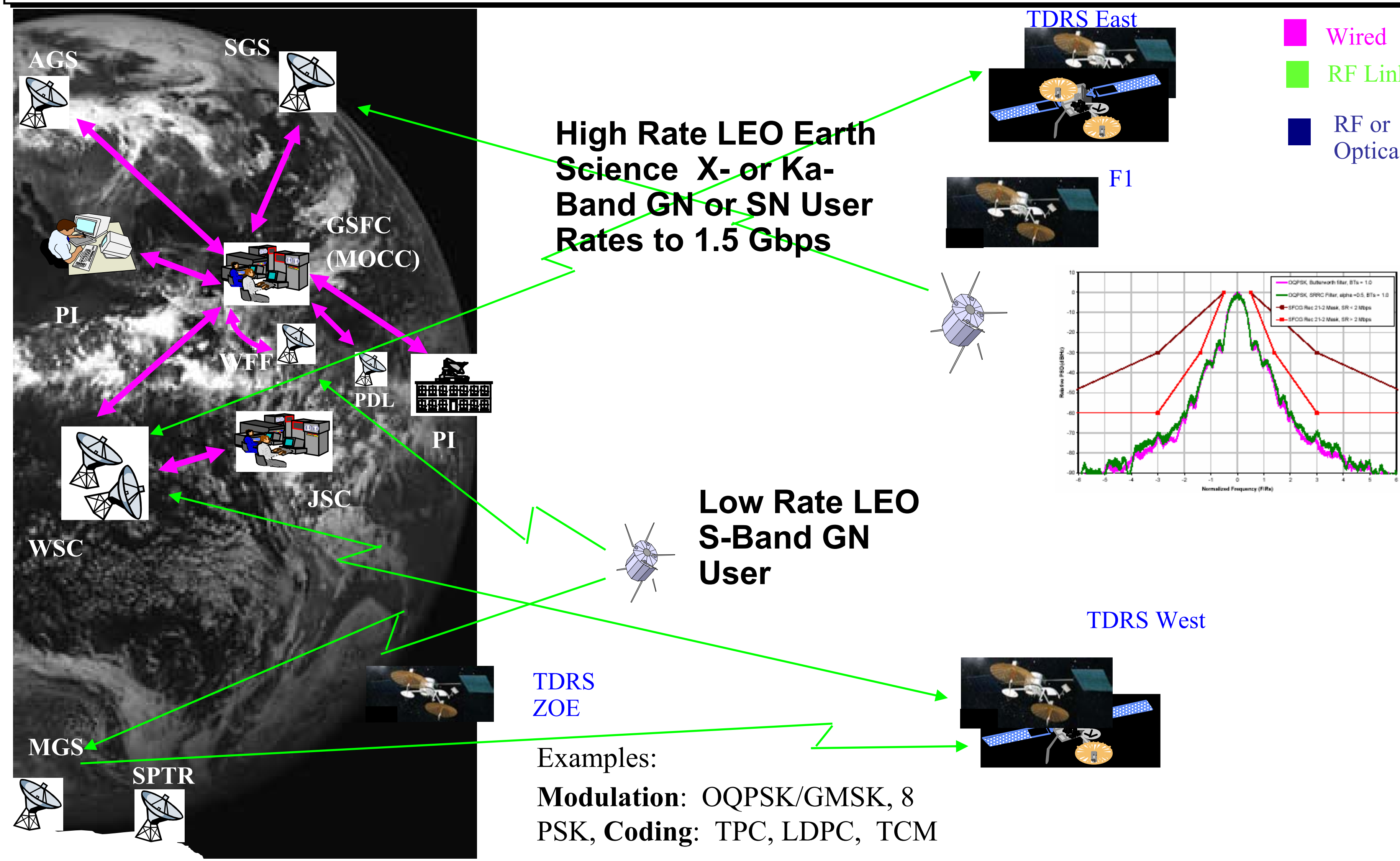
Future Mission Requirements

End to End IP Connectivity



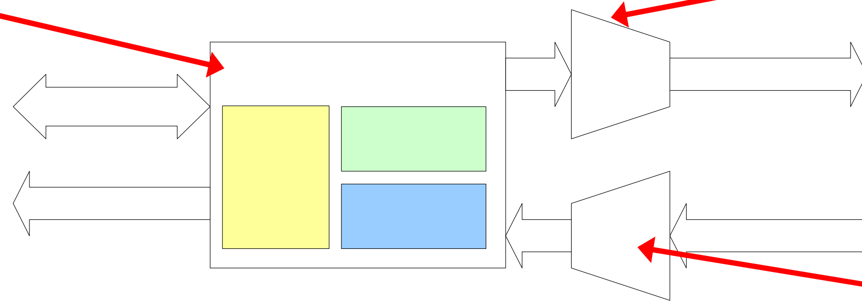
Future Mission Requirements

GN and SN Support for High Rate Bandwidth Efficient Modulation / Coding Techniques



Software Defined Radio

Software Defined Radio (SDR) uses digital, reconfigurable processors to perform functions traditionally accomplished with analog, RF or IF hardware.



SDR enables:

- **Adaptable communication architectures whose functionality changes with new mission phases and system demands**
- **In-flight and *in-situ* reconfiguration of navigation and communication subsystems**
- **Integrated navigation & communication functions**
- **Flexible systems that can support multiple modulations, coding schemes, data rates, and frequencies with the same hardware – often co-located in the same hardware**
- **Real-time user detection, identification and configuration of infrastructure (GN & SN)**

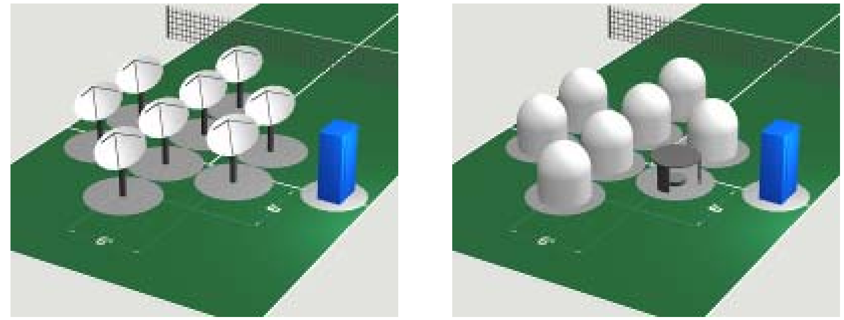
SDR Processo
Data
Mo
Channel
Coding
Navigation
Dem

Overview of Smart Antenna Research Effort

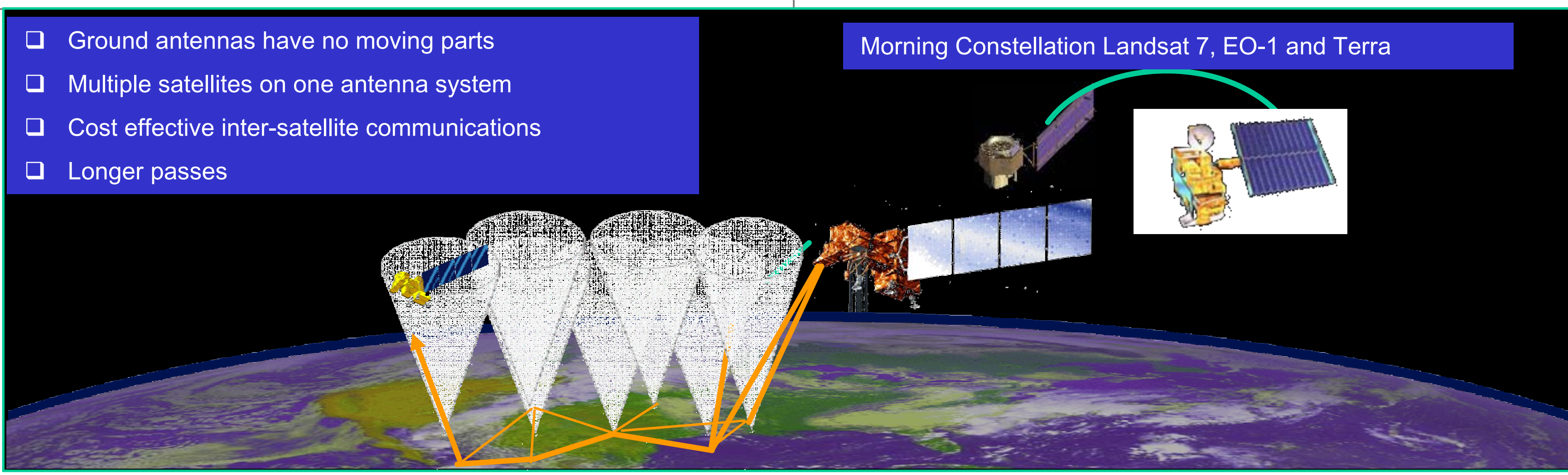
PI: Dan Mandl, NASA/GSFC, Code 584

Description and Objectives

- Validate new antenna technologies that either used separately or in combination lower cost to purchase, maintain and operate ground antennas in the X- and Ka-band for low earth orbiting satellites
- Key objectives include increased reliability by eliminating moving parts, simultaneous users on one antenna system, wider and more flexible total coverage than present GN coverage, auto-detect of satellites entering the field –of-view of antennas and auto-adjust of Gain over Noise Temperature (G/T) depending on needed gain to receive data from satellite



Conceptual Antenna System Architecture based on small dishes (left) and alternative concept based on Space Fed Lens Array (right), placed on backdrop of tennis court to visualize size.



- **Continuous cost-effective links to low earth orbiting satellites could provide a wireless communications backbone with frequencies translated and messages passed between satellites and antennas residing within metropolis areas thus enabling Sensor Webs.**

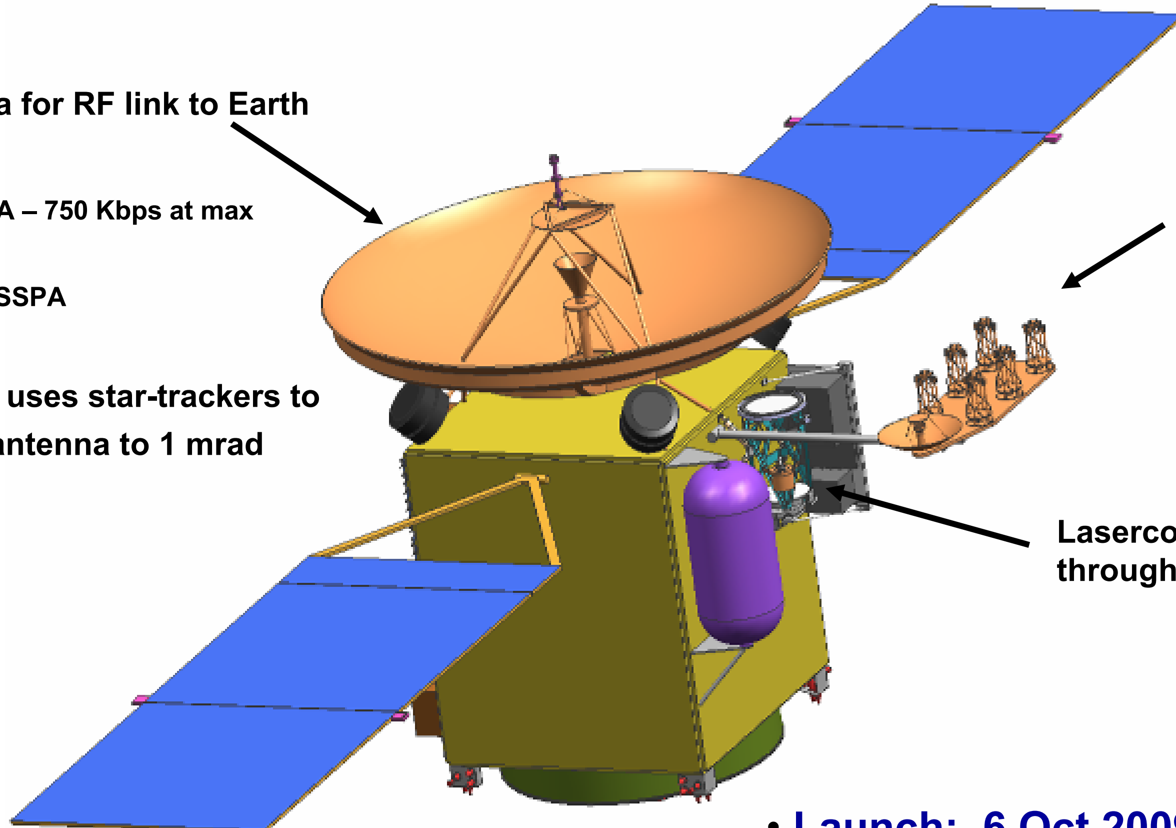
2009 Mars Telecom Orbiter (Reference Design)

3m antenna for RF link to Earth

35W Ka TWTA – 750 Kbps at max range

15W X-band SSPA

Spacecraft uses star-trackers to point this antenna to 1 mrad accuracy



Gimbaled UHF & X-Band antennas for uplinks from Mars

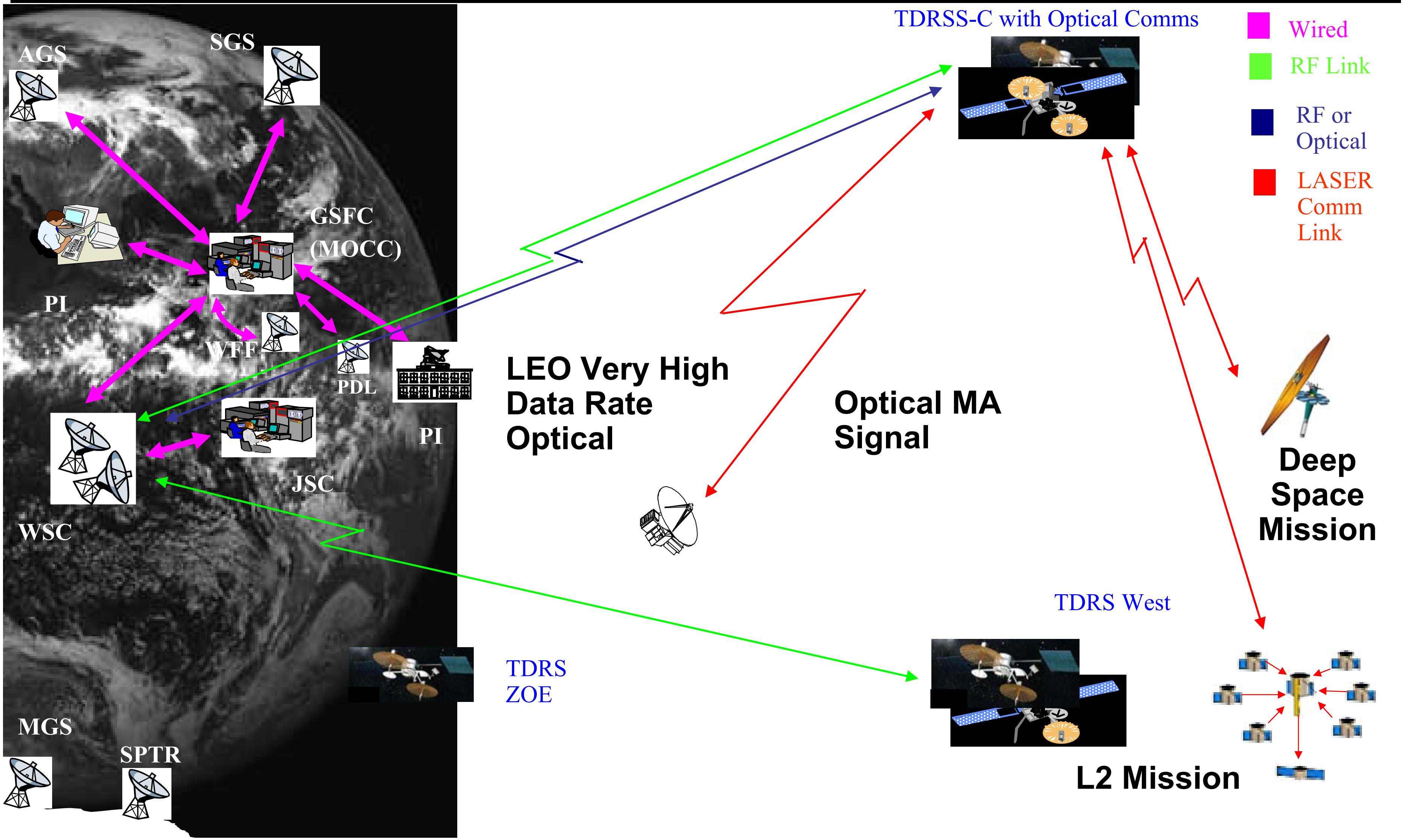
Lasercom terminal looks through hole in antenna

Mars Lasercom Terminal will not exceed 70 Kg or 150 Watts

- Launch: 6 Oct 2009
- Arrive Mars: 29 Aug 2010
- 6-hour Martian orbit
- Comm service for experiments on Mars
- 2 optical cameras

Future Mission Requirements

Optical Communications for Near Earth & Deep Space

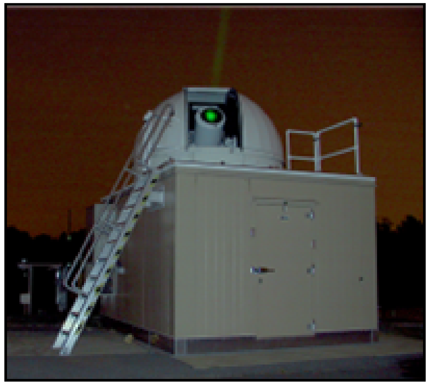


GN Evolution - SLR Component

NASA has been standard for SLR for over 30 years

Current SLR

- Single Person, Full Time Operations
- Aging Equipment, 25 Yrs. +
- Obsolete, Failure Prone HW
- 5 Hz Repetition Rate
- Aircraft Monitoring Required



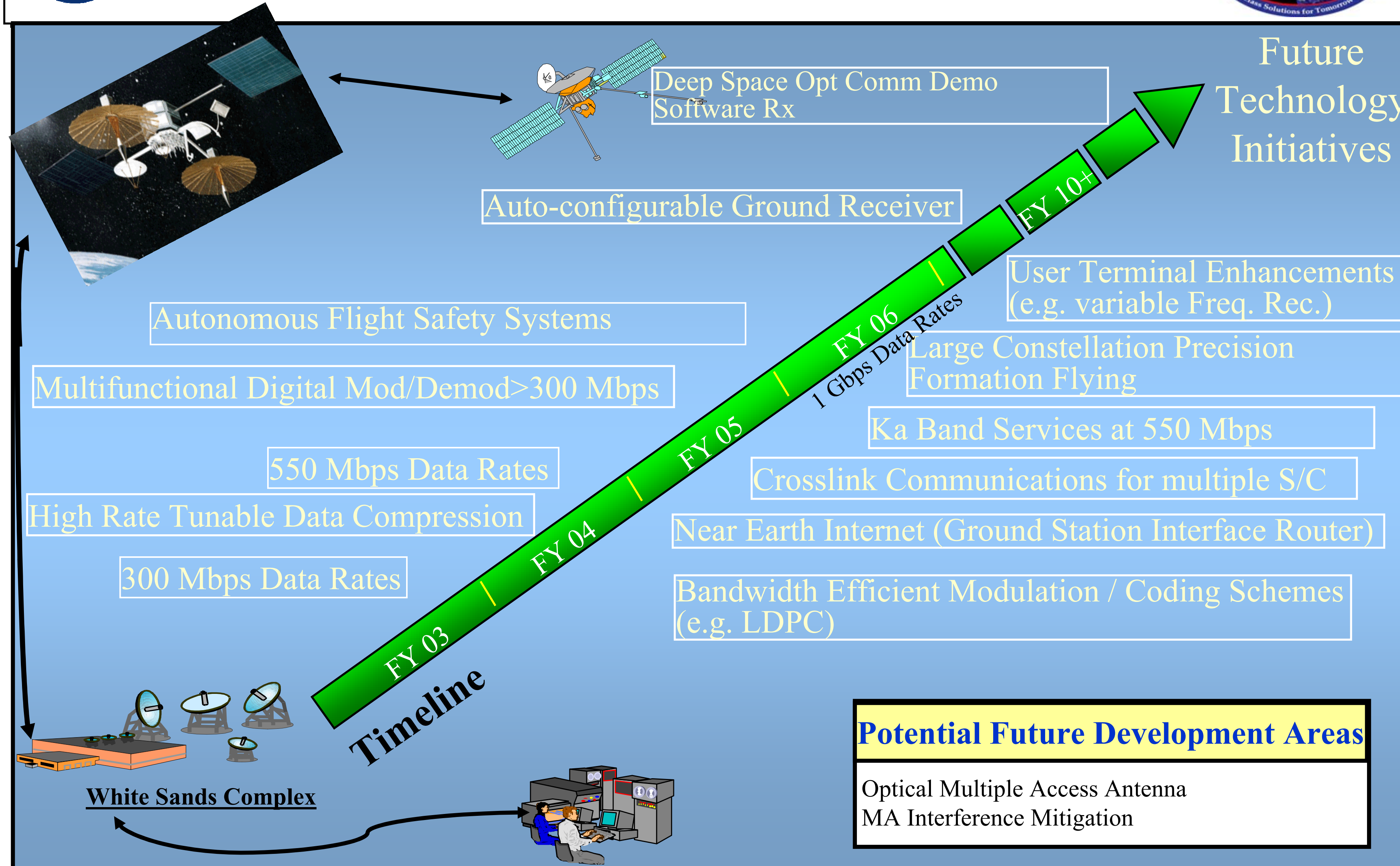
Next Generation SLR

- Autonomous, Eye-Safe, 24/7 Operations
- No Optical, Chemical, or Electrical Hazards
- Reduced Replication Costs, COTS Technology
- Centimeter Accuracy, Millimeter Precision
- 2 kHz Repetition Rate
- MTBF ~ 4 Months
- SLR up to 22,000 km range
- Automated Two-Way Communications
- HW & SW Standardization for Reduced Ops. Costs

Potential Upgrades and Uses

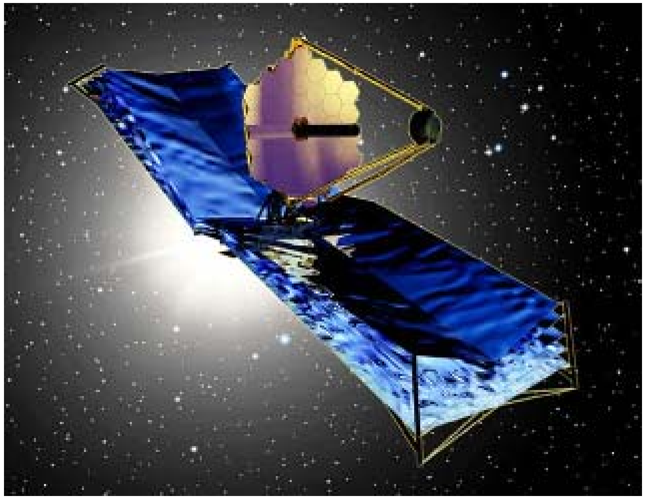
- SLR at Lunar distances
- Free Space Laser Communications
  - Multi Gigabit Data Download
  - GEO, HEO, MEO, LEO, UAV and Lunar

Future Technology Advances
Technology Initiatives



Space Communications Enabling the Future

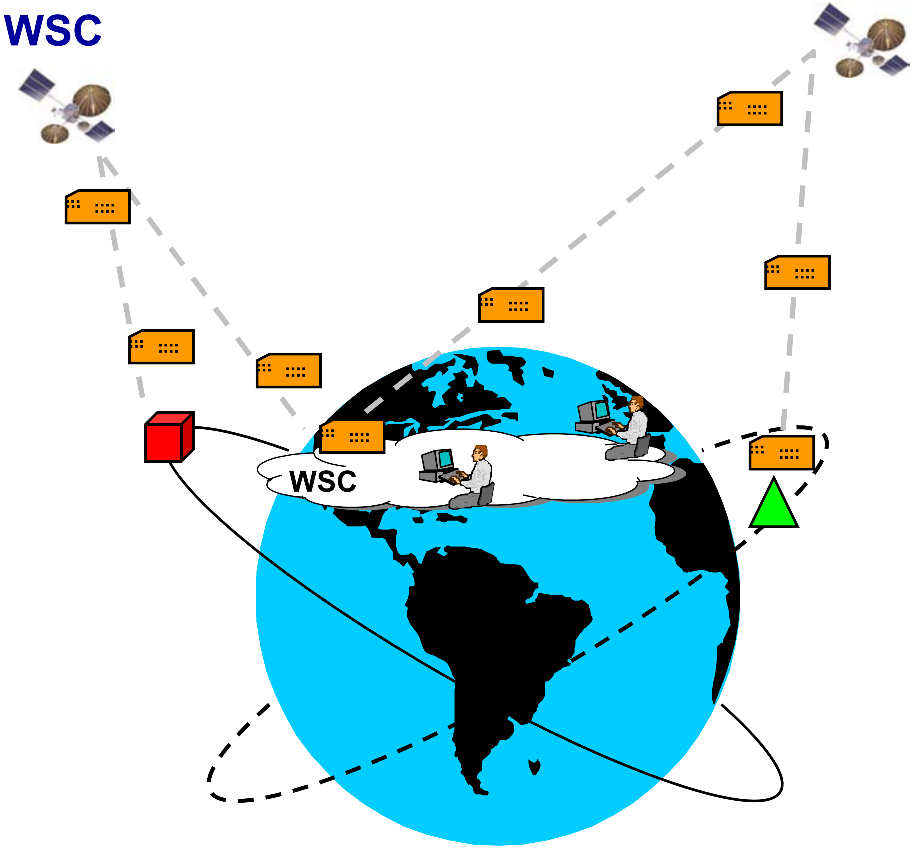
- Revolutionary new Science and Exploration requires new (and mature) Space Communications
  - Architectures
  - Technologies
  - Standards
  - Partnerships



Backup

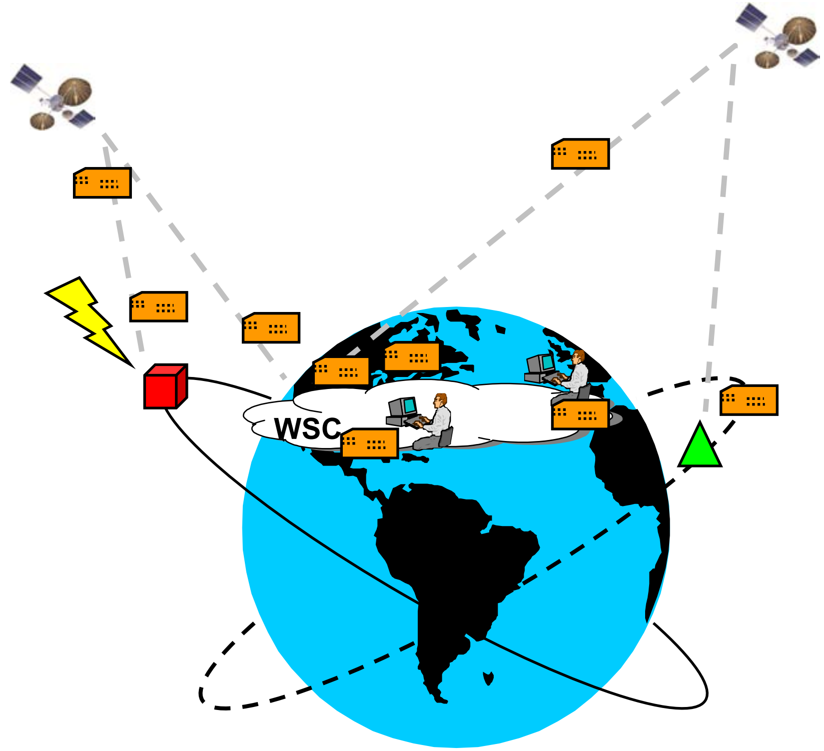
Virtual Crosslink -- Sensor Web

- Combination of TDRSS links and ground network provide real-time crosslink between multiple user spacecraft
- Sequence, leveraging RTN DAS/Fast-Forward
  - RTN DAS: Spacecraft → TDRS → WSC
  - IP routing at WSC routers
  - Fast Forward: WSC→TDRS → 2nd spacecraft
- Possible to connect to spacecraft on opposite sides of the earth
- No data destination configuration required at WSC
- Routing between systems handled by standard automated Internet techniques

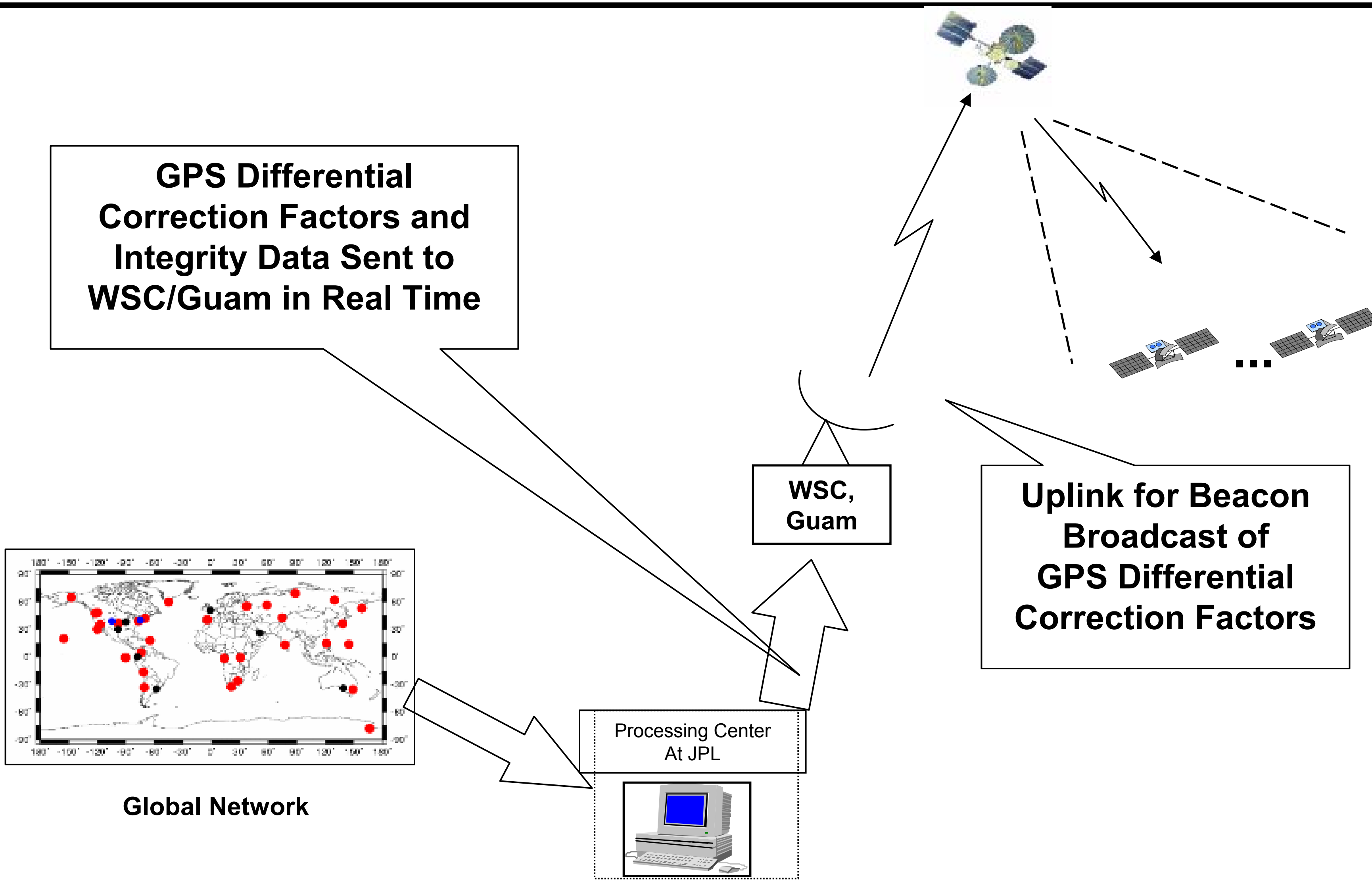


Fast Forward Example: Science Alert

- One user spacecraft detects event (e.g., Gamma Ray Burst) and wants to send notification to many other ground/space systems across an IP network
- SN RTN DAS / FF, combined with SNIS, enables inter-connection of space elements and ground networks into one addressable network
  - Spacecraft detects event and addresses alert packet to one or more addresses
  - Packet relayed through TDRSS to WSC, via RTN DAS
  - Address causes router at WSC to send alert packets to one or more network nodes
    - FF used to send packets to desired spacecraft

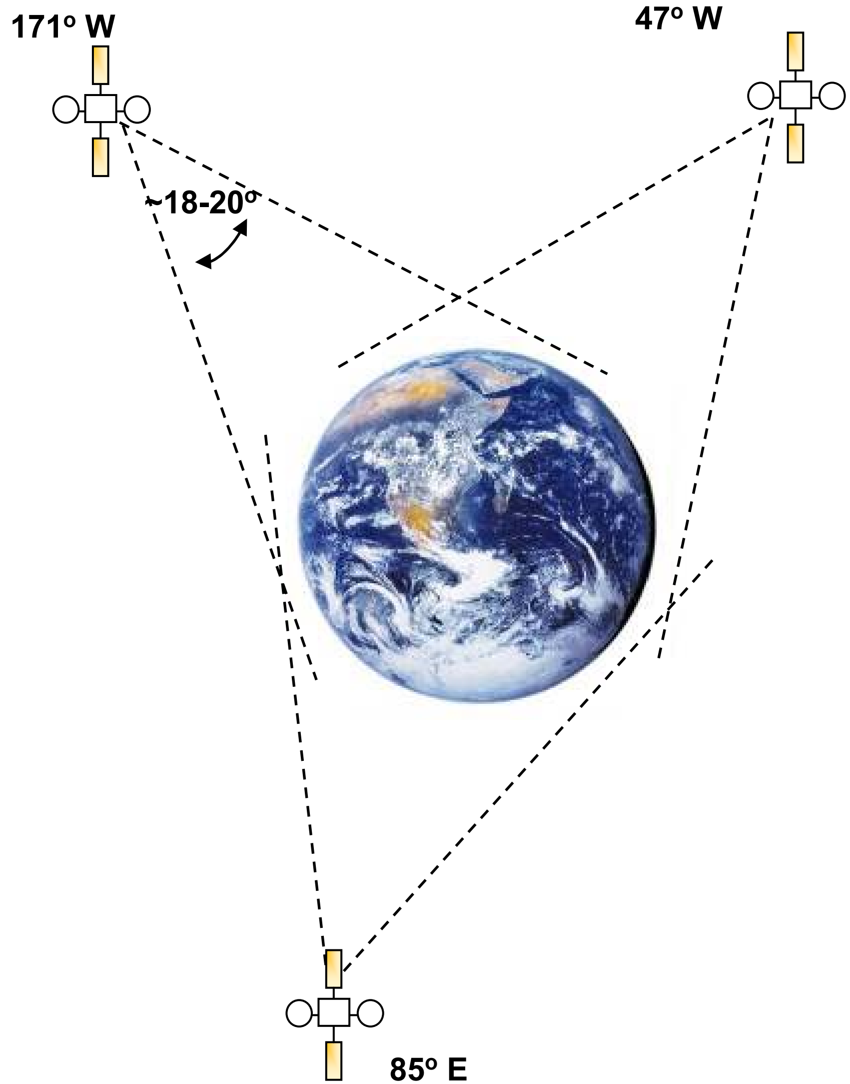


Forward Beacon Concept



TDRSS Coverage/Beacon Concept

- 3 satellites required, as shown
- Each TDRS provides conical beam (~18 - 20°) to continuously cover field-of-view up to ~ 1000 km
- 24 x 7 S-Band MA broadcast from each TDRS provides continuous updates of GPS correction data to all LEO s/c in FOV
- MA broadcast baseline
  - PN code modulated / BPSK data stream
  - Unique PN code per TDRS
  - 100 bps data rate, rate 1/2 FEC (includes desired data + overhead)
  - Repeated every 6 sec, with GPS correction updates
- Continuous LEO tracking within FOV
- Make-before-break during TDRS-to-TDRS handover, to ensure no data loss



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Potential Upgrades and Uses

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- Free Space Laser Communications
    - Multi Gigabit Data Download
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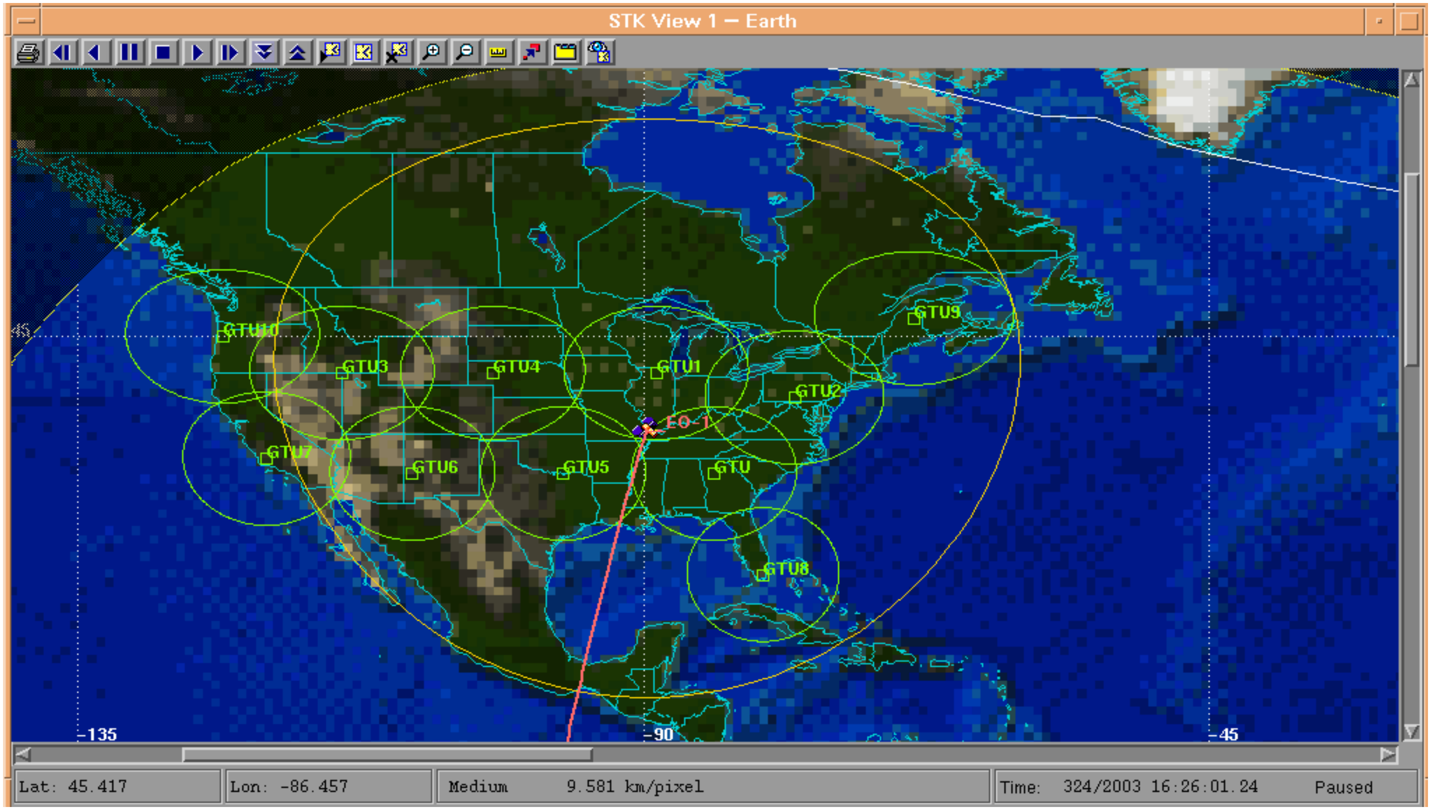
Why Smart Antennas for GN

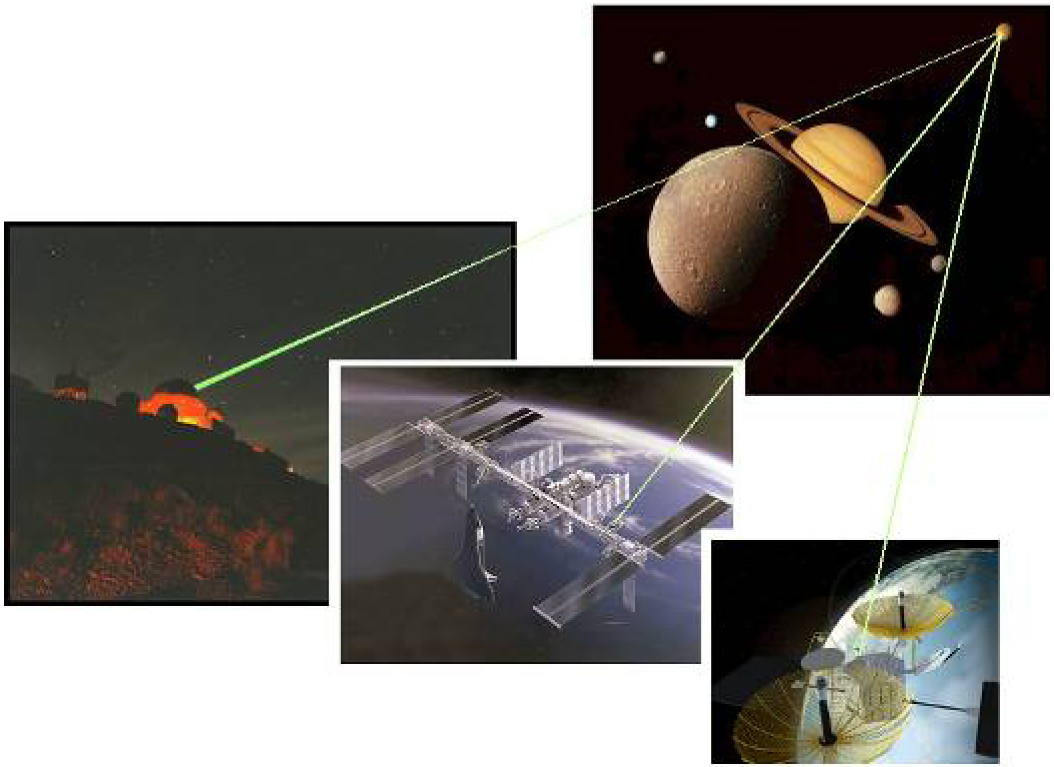
- Reliable
- No moving parts (or at least minimal moving parts) - electronically steered
- Use multipath to enhance signal rather than diminish
- Low cost
- Enable continuous coverage
- Enable inter-satellite communications similar to cell phones
- Capability to handle multiple satellites on one antenna system
- Instantaneously scalable to handle multiple scenarios since electronically reconfigurable

Continuous Coverage



- Ultimate goal is to get continuous coverage for low earth orbiting satellites such as EO-I. Need cost-effective, easily networked and scalable ground stations.
- STK analysis shows that with a 45 degree cone, 11 of these low cost ground stations could provide continuous coverage over U.S. Hope to do better than 45 degrees thus reducing number of antenna systems needed.

Deep Space Lasercom Orbiting Earth Terminal Study Proposal



April 16, 2004
Joint NASA GSFC/JPL Deep Space Lasercom Team

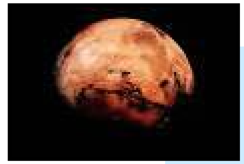
Key Elements of Study

- **What?**
  - Advance NASA's deep space laser communication capabilities by investigating the development of technologies needed for orbiting Earth terminals.
- **Why?**
  - A terminal above the Earth may be required in order to support the highest speed bi-directional communications to Mars and beyond. Two such terminals would provide continuous availability from one location.
- **How?**
  - Develop concepts and designs for various options of Earth-orbiting optical terminals develop cost and performance estimates, and identify risks and opportunities for technology demonstrations using ISS, free flyers, or balloon missions as platforms.
- **When?**
  - The study is needed so that NASA can use the results in a trade-off study with ground-based assets and decide on a long-range plan for optical communications assets.
  - If decision is timely, there could be an opportunity to demonstrate technology with the Mars Laser Communication Demonstration project (launch date of October 2009) or to influence other major procurements (e.g. TDRSS-C).
- **Who?**
  - A GSFC/JPL team.
  - Additional support from Industry.
- **How Much?**
  - $850K estimated for a 6 month study.
  - Costs for potential risk reduction demonstrations will be estimated by the study.

Deep Space Lasercom: Path to the Future

Technology

- Lasercom
- Network protocols & management
- Demonstrations & risk reduction

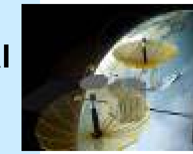


Mars

- Tracking capability for landed assets

TDRSS-C, Free-Flyer, or Ground-based

- Deep space lasercom terminal
- Possible connectivity to NASA/TCM backbone



Architecture & Technology Development

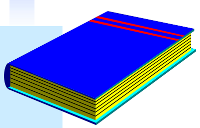
Planning & Preparation

Evolution

High-Performance Interplanetary Network

Standards

- Lasercom technology selection
- Network management, security, protocols
- Government lasercom working group; LIS



Flight Demo

- ISS, Free-Flyer, or Balloon
- Receiver terminal with upgrade options
- Flight heritage for TDRSS and others

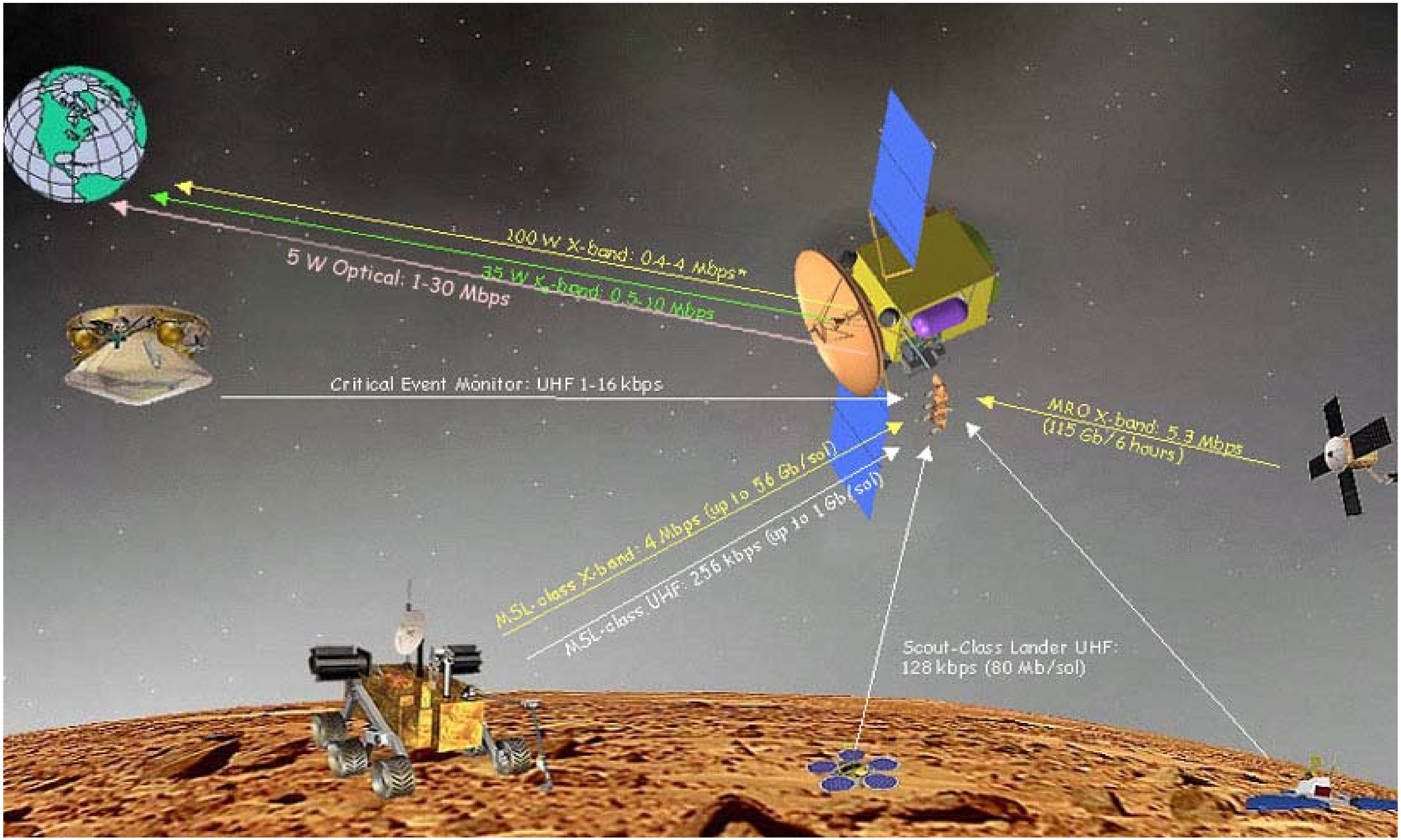
JIMO

Codes S and T Exploration Missions

- Deep-space mission
- Near-Earth receiver

Cost-Effective Approach to Achieve Early Capability

Overview of MTO Links



* Constrained by X-band frequency allocation

Primary Objectives for New Satellite LASER Ranging System

- Replace existing Satellite Laser Ranging systems which are outdated, failure-prone and require full-time operators
- Reduce replication and operations costs through standardization, COTS technology, and automation
- Unmanned, eye-safe 24/7 tracking to satellites up to 22,000 km range
- Free of optical, electrical, and chemical hazards
- Track to centimeter accuracy, millimeter precision
- Mean time between failures: ~ 4 months
- Automated two-way communication with central processor to obtain tracking schedule and for data delivery

Potential Objectives for New SLR System

- Allow future incorporation of optical communication receivers
- Track satellites at lunar distances

Current Development System

SLR Summary

- The SLR2000 prototype is now tracking satellites but there is a lot to do before the system is considered operational (even in a semi-automated state).
- We expect to have a system that can perform semi-automated tracking of LAGEOS and ETALON within the next year.
- Real-time determination of signal processing parameters and selection of satellite tracks based upon the sky map should occur sometime in CY2005.
- There do not appear to be any insurmountable technical issues – we just need to work out the remaining problems.
- Funding is the real question at this point.